The Nation's Nuclear Physics Program and the Role of Government

East Coast Conference for Undergraduate Women in Physics

January 17, 2014

Dr. Jehanne Gillo

Office of Nuclear Physics

Department of Energy

Why Am I Here?

You have many options down the road!

- Experimental physics? Theoretical physics?
- Basic research? Applied sciences?
- After College – work? Advanced degree? Masters? Ph.D.?
- After Ph.D. – work? Postoctoral appointment?
- What kind of work?
  - Academic?
  - National Laboratory?
  - Industry?
  - Government?

- **Government develops strategic direction of science program and pays the bills!**

DOE Office of Science

The Office of Science (SC) is the single largest supporter of basic research in the physical sciences in the United States.

The Office of Science is led by a Presidentially-nominated, Senate-confirmed Director and three senior career federal Deputy Directors.

- Builds and operates scientific facilities (30) and major instrumentation
- User facilities used by 29,000 researchers and their students annually
- Facilities are located at labs and universities; open to researchers on peer-reviewed basis
- Include particle accelerators, light sources, neutron scattering facilities, supercomputers, high speed networks and genome sequencing facilities
- SC is steward of 10 out of 17 DOE world-class national laboratories

- **Principle supporter of graduate students and postdoctoral researchers**
- **Undergraduate research internships at national labs**

SC Program Offices

- Advanced Scientific Computing Research:
  Deliver Computing for the Frontier of Science
- Basic Energy Science:
  Advance the Basic Sciences for Energy Independence
- Biological and Environmental Research:
  Harness the Power of Our Living World
- Fusion Energy Science:
  Bring the Power of the Stars to Earth
- High Energy Physics:
  Explore the Fundamental Interactions of Energy, Matter, Time and Space
- Nuclear Physics:
  Explore Nuclear Matter from Quarks to Stars
- WorkForce Development for Teachers and Scientists:
  Train the Next Generation of Scientists and Engineers to Maintain U.S. Scientific and Technological Leadership

Nuclear Science

Nuclear Physics (Science) is the study of the properties and interactions of atomic nuclei and nuclear matter in terms of the fundamental forces and particles of nature.

Nuclear processes are essential for the world we live in.

- They are necessary for sustaining life on earth today
- For understanding how our universe evolved
- Relevant to the nation's energy, security and economical interests.

The Federal Government supports research in nuclear physics research:

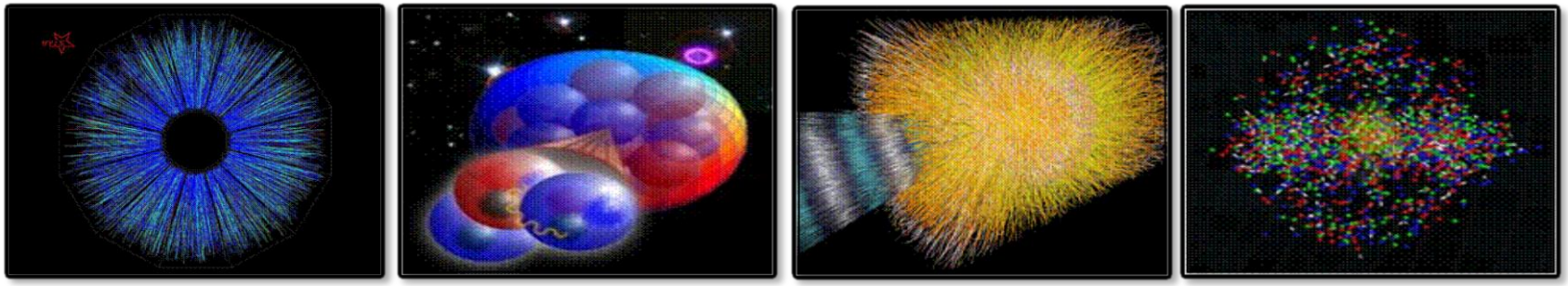
- To advance our knowledge in this fundamental science because of its relevance to the nation's economic, security and environmental needs.
- To educate and enlarge the nation's pool of technically trained talent, primarily at the graduate student and postdoctoral levels, for the nation's needs.
- To facilitate transfer of knowledge and technology acquired to support the nation's needs.

Nuclear Physics

Discovering, exploring, and understanding all forms of nuclear matter

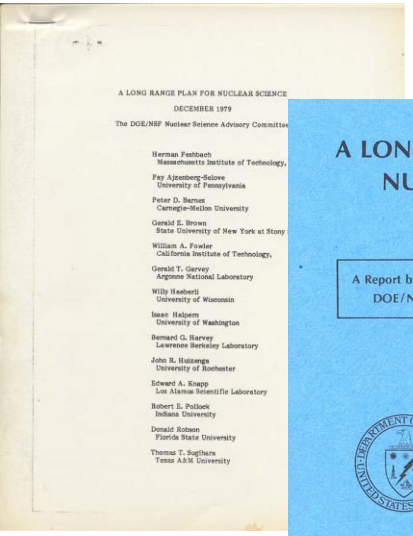
The Scientific Challenges

- The existence and properties of nuclear matter under extreme conditions, including that which existed at the beginning of the universe
- The exotic and excited bound states of quarks and gluons, including new tests of the Standard Model
- The ultimate limits of existence of bound systems of protons and neutrons
- Nuclear processes that power stars and supernovae, and synthesize the elements
- The nature and fundamental properties of neutrinos and neutrons and their role in the matter-antimatter asymmetry of the universe

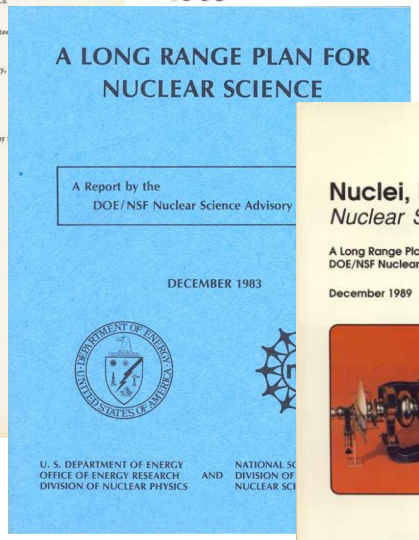


Defining the Science – Long Range Plans

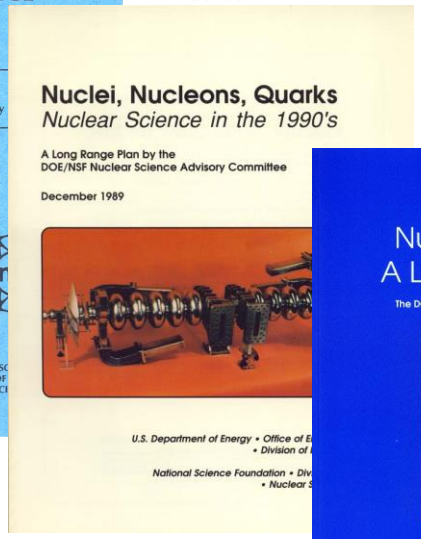
1979



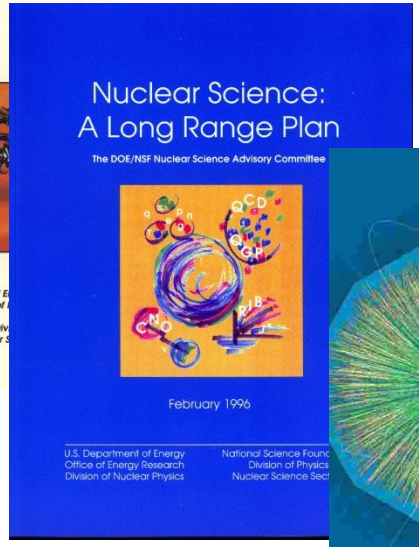
1983



1989

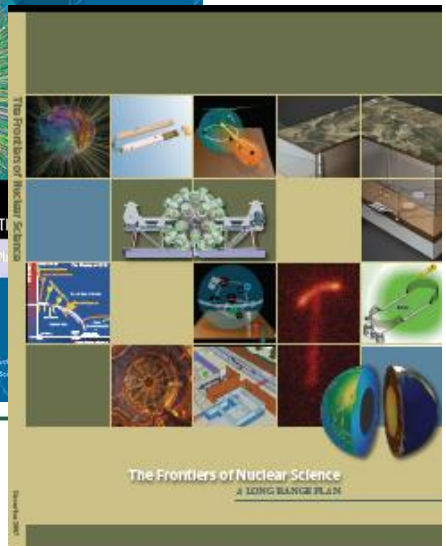


1996



2002

2007



The Long Range Plans have:

- Identified the scientific opportunities
- Recommended scientific priorities

Effectively defining the field of Nuclear Physics for the Nation

Last LRP in 2007

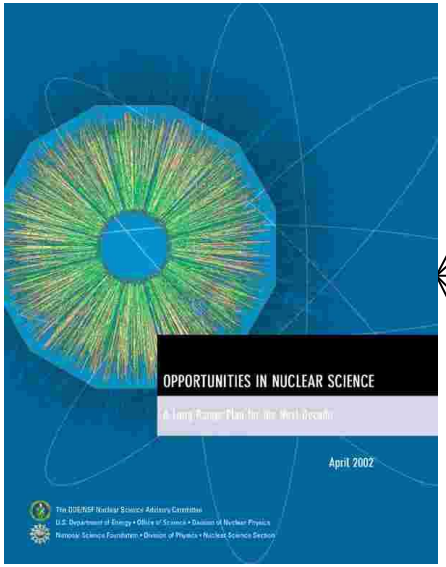
Nation's leadership role today is largely a result of:

- The responsible/visionary **strategic planning** embodied in the NSAC Long Range Plans
- Federal government's decision to utilize the guidance and provide the needed resources

Scientific Thrusts

Nuclear Physics has five major scientific thrusts in which:

- Progress has been impressive
- Significant results can be expected in the future
- Outstanding scientific opportunities have been identified that require investments



Major Scientific Thrusts of the Field

Quark Structure of Matter

Structure of nucleons & nuclei in terms of their quark substructure

Phases of Nuclear Matter

Properties of hot, dense nuclear matter
Search for evidence of a quark-gluon plasma

Nuclear Structure & Dynamics

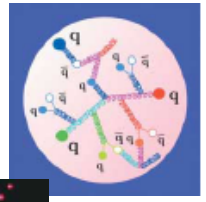
Nuclear structure at extreme excitation, angular momentum, and proton/neutron ratios

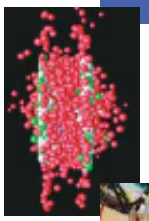
Nuclear Astrophysics

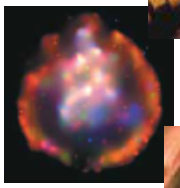
Reaction rates and simulations relevant to stellar burning and supernovae phenomena

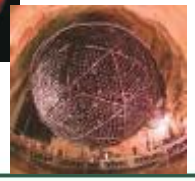
Fundamental Symmetries

The nucleon/nucleus as a laboratory to test the Standard Model and fundamental theories









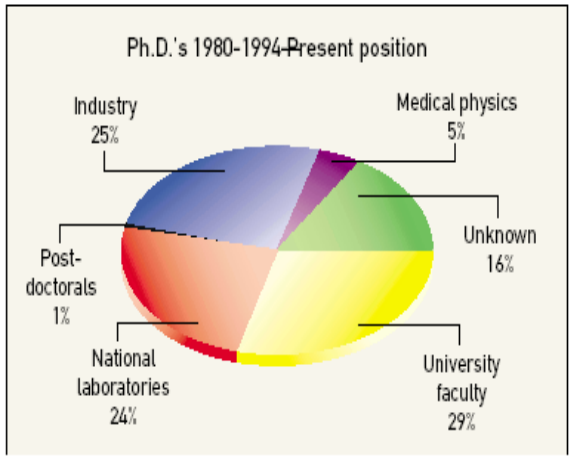
Training the Scientific and Technical Workforce

Graduate Student and Postdoctoral Associate Training

- NP supports graduate students and post doctoral appointments (postdocs)
- About two-thirds (2/3) of these highly trained scientists go on to careers outside of basic nuclear physics research
- Dozens of outreach activities are carried out each year by nuclear scientists at laboratories and universities
- Specific activities such as the Conference Experience for Undergraduates are aimed at attracting the brightest students to nuclear science
- Workshops and summer schools enrich the experience of graduate students and postdoctoral associates

New Opportunities for Workforce Training in NP

- SC Early Career Awards for university faculty and laboratory scientists
- SC Graduate Fellowship Awards; three-year awards for graduate students
- FOA for R&D on Alternative Isotope Production Techniques; supports additional postdocs and students in nuclear chemistry



Ph.D. Recipients go on to careers in Academia, Medicine, National Laboratories, and Industry

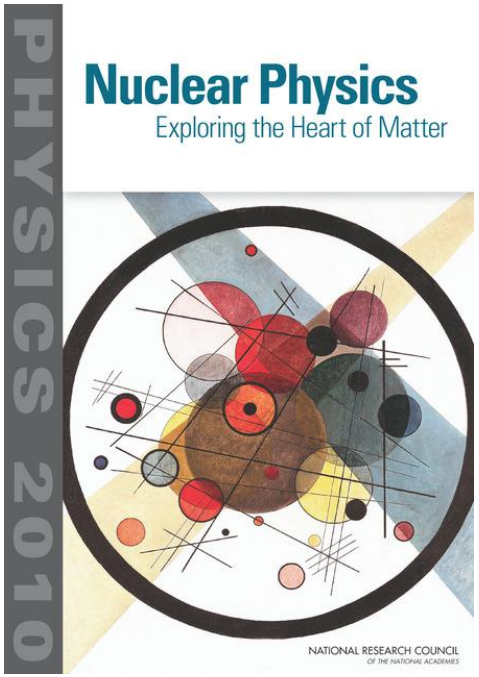
Conference Experience for Undergraduates

SC NP is the Primary Federal Steward of U.S. Nuclear Science

DOE/SC is the largest supporter of nuclear physics in the U.S. and operates large National User Facilities

Responsible for Strategic Planning and Funding

- Identify the scientific opportunities for discoveries and advancements
- Build and operate forefront facilities to address these opportunities
- Develop and support a research community that delivers significant outcomes
- Work with other agencies/countries to optimize use of U.S. resources



Goals

- **World-class facility research capabilities**
  - to make significant discoveries/advancements
- **A strong, sustainable research community**
  - to deliver significant outcomes
- **Forefront advanced technologies, capabilities**
  - for next-generation capabilities
- **A well-managed and staffed, strategic sustainable program**
  - that ensures leadership/optimizes resources

Deliverables

- New insights and advancements in the fundamental nature of matter and energy
- New and accumulated knowledge, developed and cutting-edge technologies, and a highly-trained next-generation workforce that will underpin the Department's missions and the Nation's nuclear-related endeavors
- Isotopes for basic and applied sciences

Nuclear Physics Program in the U.S.

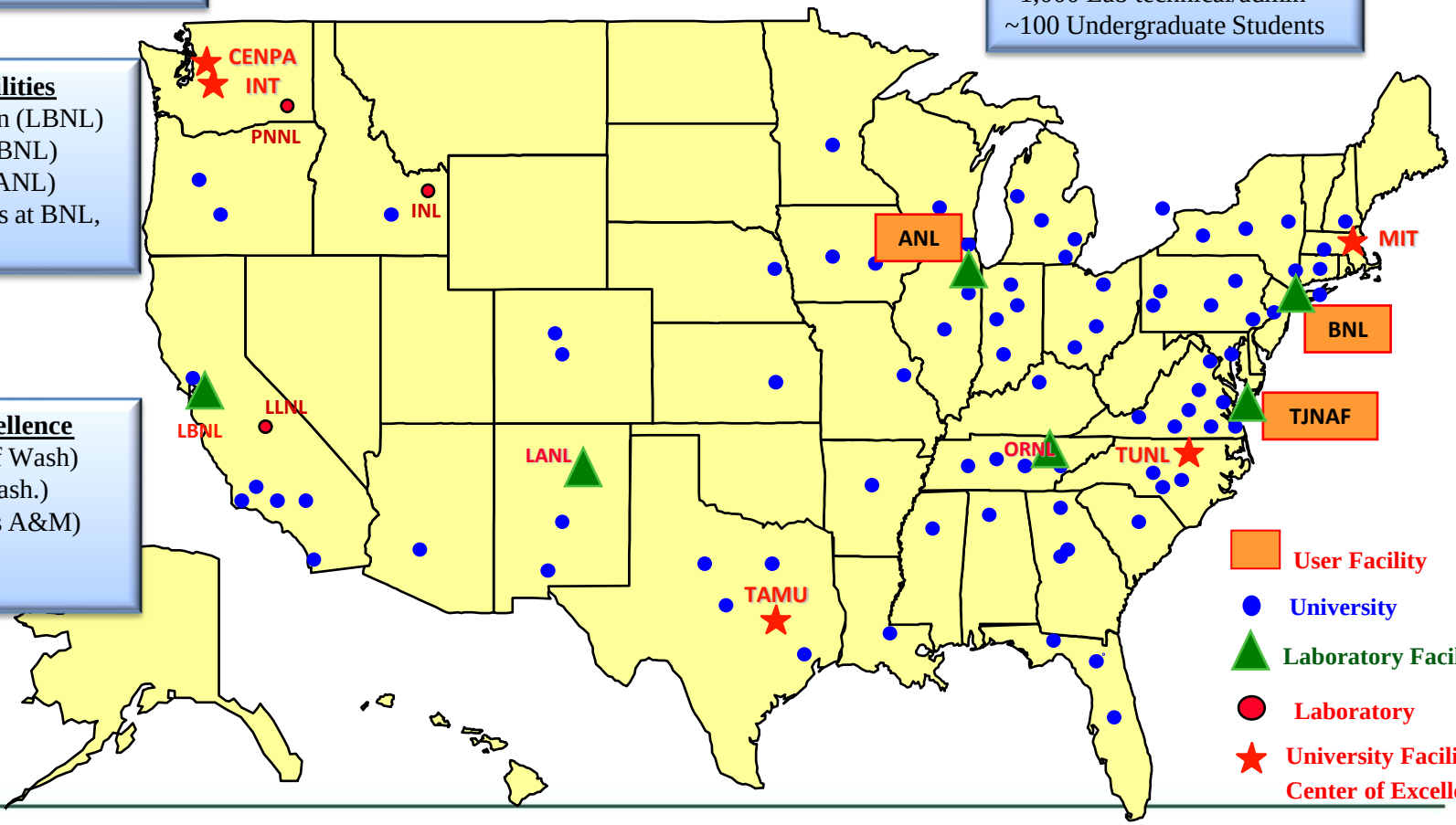
National User Facilities
- RHIC (BNL)
- CEBAF (TJNAF)
- ATLAS (ANL)
- ~3,000 users

Research Groups
- 9 National Laboratories
- 85 Universities

NP Workforce
~740 Faculty & Lab Res Staff
~340 Post-docs
~540 Graduate Students
~1,000 Lab technical/admin
~100 Undergraduate Students

Other Lab. Facilities
- 88-Inch Cyclotron (LBNL)
- 200 MeV BLIP (BNL)
- 100 MeV IPF (LANL)
- Hot Cell Facilities at BNL, LANL, ORNL

Centers of Excellence
- CENPA (U. of Wash)
- INT (U. of Wash.)
- TAMU (Texas A&M)
- TUNL (Duke)
- REC (MIT)



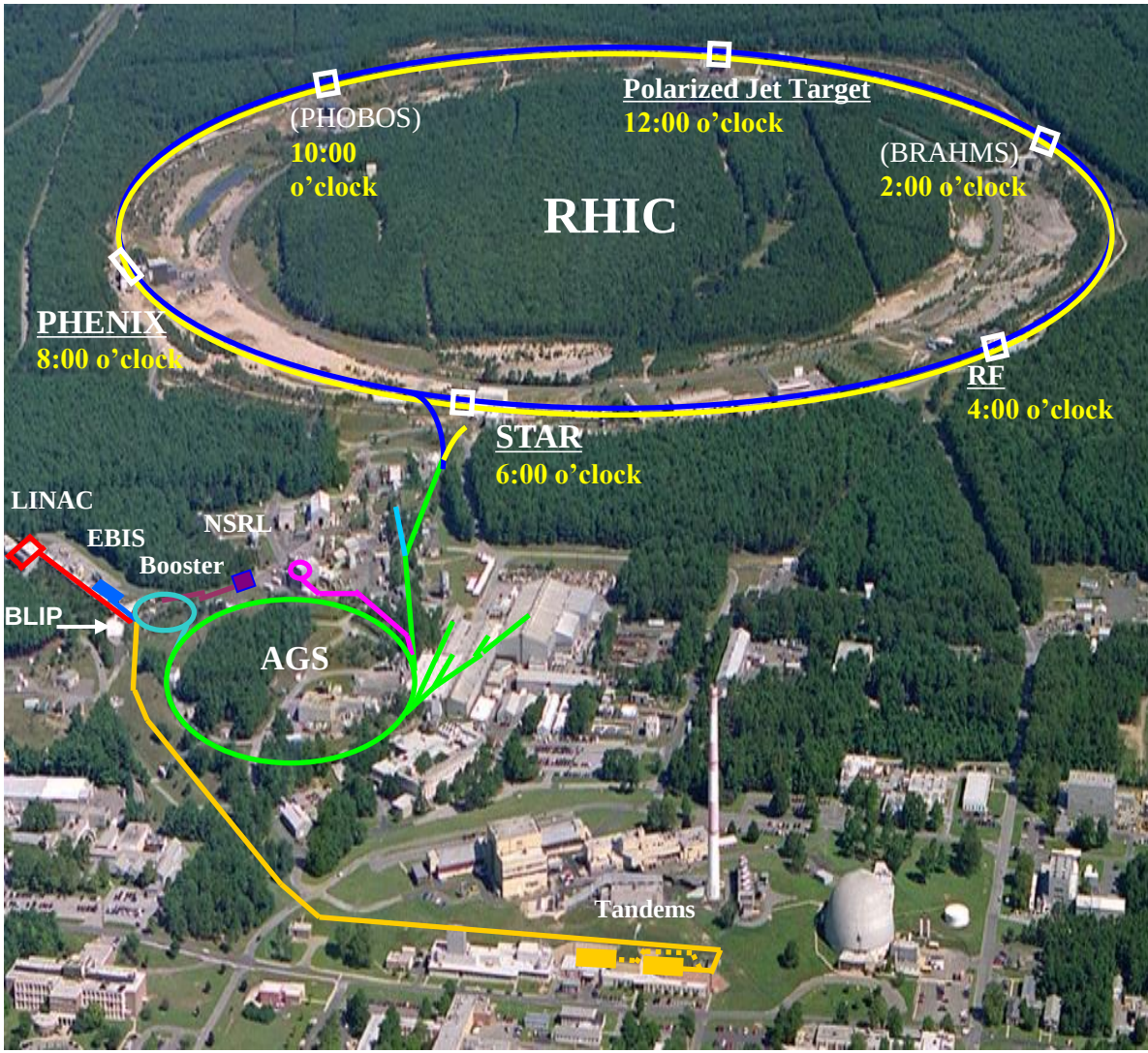
Research at the Relativistic Heavy Ion Collider

RHIC discovered that when the universe was 100,000 hotter than the center of the sun and only microseconds old, it was filled with a liquid like water, ─ only flowing 10 times more easily - a "***perfect fluid*** !"

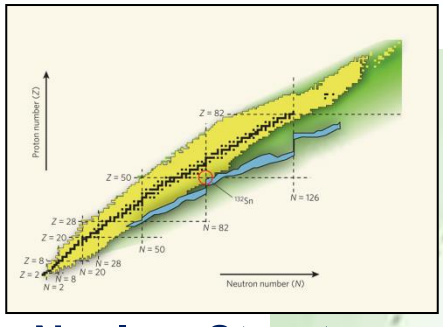
As the universe expanded and cooled, the matter did not freeze, but it turned into a gas, with the fundamental particles, quarks and gluons, eventually condensing into the mixture of hydrogen and helium we observe today.

Continued experiments at RHIC are needed to answer the question why the universe evolved this way?

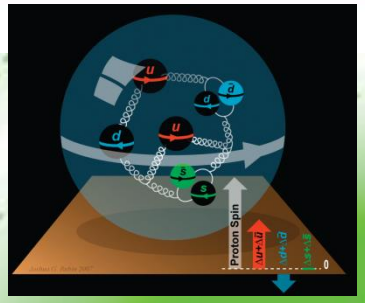
The underlying science has remarkable connections to other natural phenomena, e.g., to high temperature superconductors, to ultra-cold atoms, and - most astonishingly - to black holes. If we can understand what causes the quark-gluon fluid to be "perfect", we can understand the origin of all visible matter in the universe.



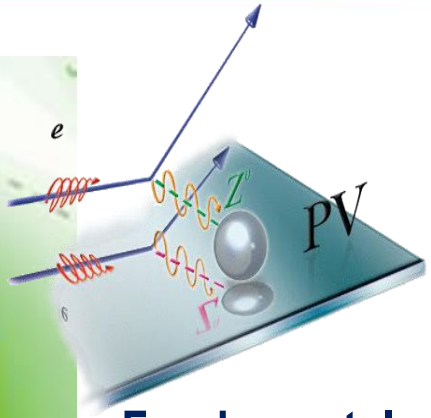
JLAB: A Multi-Thrust Laboratory for Nuclear Science



Nuclear Structure

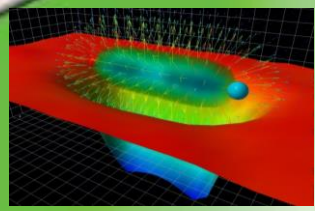


Structure of Hadrons



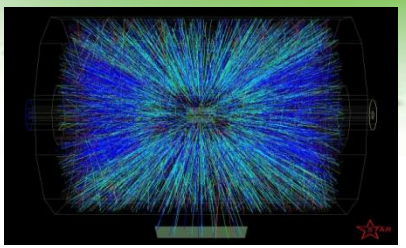
Fundamental Forces & Symmetries

Medical Imaging



Quark Confinement

Accelerator S&T



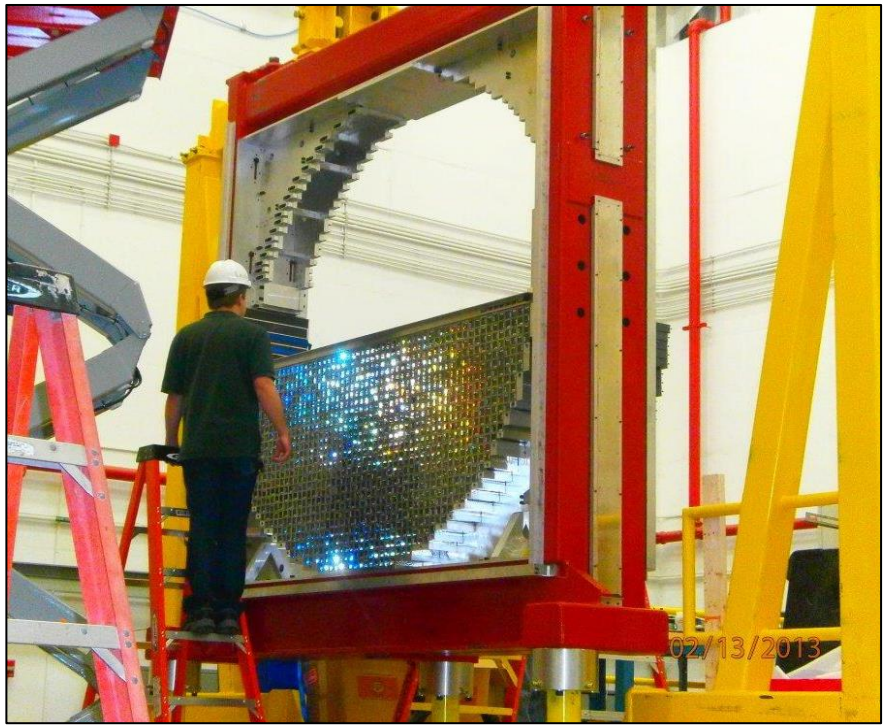
Hadrons from QGP

Theory and Computation

The 12 GeV CEBAF Upgrade at TJNAF is 75% Complete

With the completion of the 12 GeV CEBAF Upgrade, researchers will address:

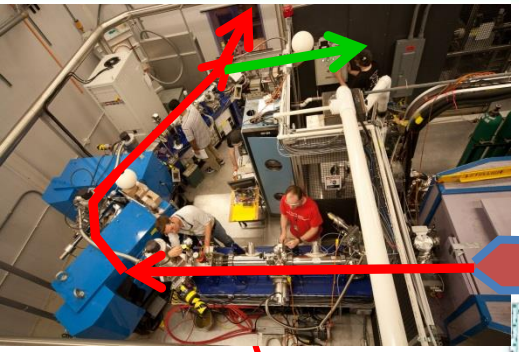
- The search for exotic new quark anti-quark particles to advance our understanding of the strong force
- Evidence of new physics from sensitive searches for violations of nature's fundamental symmetries
- A detailed microscopic understanding of the internal structure of the proton, including the origin of its spin, and how this structure is modified when the proton is inside a nucleus



The Forward Calorimeter (FCAL) being assembled in the newly constructed Experimental Hall D.

Experimental Hall B readied for construction of the 12 GeV CEABAF Large Acceptance Spectrometer (CLAS12)

ATLAS at ANL Uniquely Provides Low Energy SC Research Opportunities Through Most of the Coming Decade

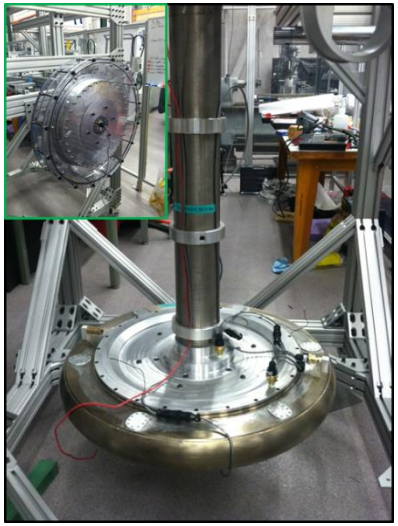


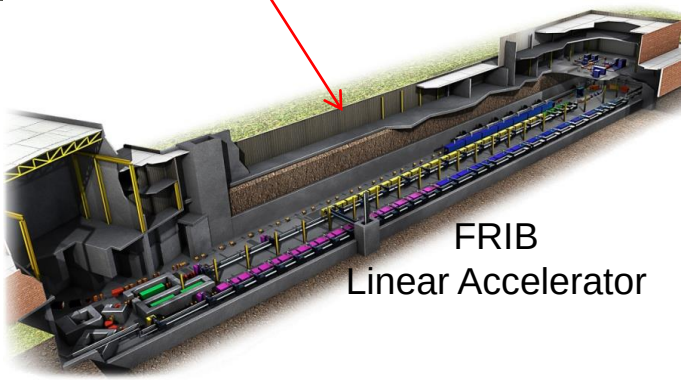
ATLAS

ATLAS is a unique premier Stable Beam Facility for research on Nuclear Structure & Nuclear Astrophysics

The Future of this Scientific Subfield in the U.S. Depends on Construction of the Facility for Rare Isotope Beams

FRIB Site February 2013





FRIB
Linear Accelerator

Left: Titanium-shell beam dump prototype in final preparation for testing under rotation, a capability essential to handle very high power FRIB beams

FRIB will increase the number of isotopes with known properties from ~2,000 observed over the last century to ~5,000 and will provide world-leading capabilities for research on:

Nuclear Structure

- The ultimate limits of existence for nuclei
- Nuclei which have neutron skins
- The synthesis of super heavy elements

Nuclear Astrophysics

- The origin of the heavy elements and explosive nucleo-synthesis
- Composition of neutron star crusts

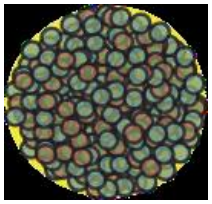
Fundamental Symmetries

- Tests of fundamental symmetries, Atomic EDMs, Weak Charge

This research will provide the basis for a model of nuclei and how they interact.

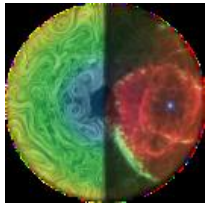
FRIB Science Will be Transformational

FRIB Science is Important for the Nation: Articulated by the NRC RISAC Report (2006), NSAC LRP (2007), NRC Decadal Survey of Nuclear Physics (2012)



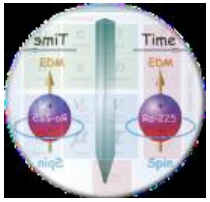
Properties of nuclei

- Develop a predictive model of nuclei and their interactions
- Many-body quantum problem: intellectual overlap to mesoscopic science, quantum dots, atomic clusters, etc.



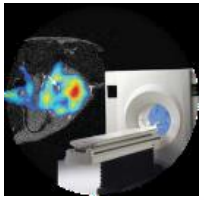
Astrophysical processes

- Origin of the elements of the cosmos
- Explosive environment: novae, supernovae, X-ray bursts …
- Properties of neutron stars



Tests of fundamental symmetries

- Effects of symmetry violations are amplified in certain nuclei



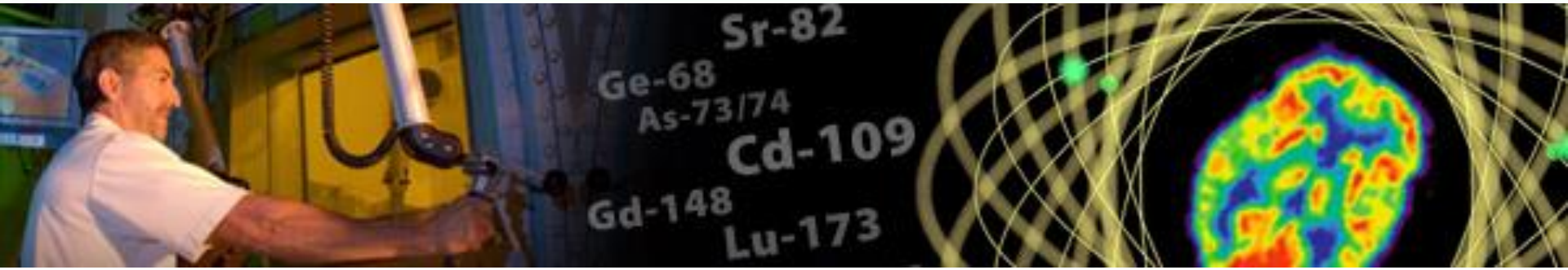
Societal applications and benefits

- Bio-medicine, energy, material sciences
- National security

"Data to date on exotic nuclei are already beginning to revolutionize our understanding of the structure of atomic nuclei. FRIB will enable experiments in uncharted territory at the limits of nuclear stability. FRIB will provide new isotopes for research related to societal applications, address long-standing questions about the astrophysical origin of the elements and the fundamental symmetries of nature."

2012 NRC Decadal Study

Isotope Program Mission



The mission of the DOE Isotope Program is threefold

- Produce and/or distribute radioactive and stable isotopes that are in short supply, associated byproducts, surplus materials and related isotope services.
- Maintain the infrastructure required to produce and supply isotope products and related services.
- Conduct R&D on new and improved isotope production and processing techniques which can make available new isotopes for research and applications.

Produce isotopes that are in short supply only – The Isotope Program does not compete with industry

More than 225 customer orders in FY2013

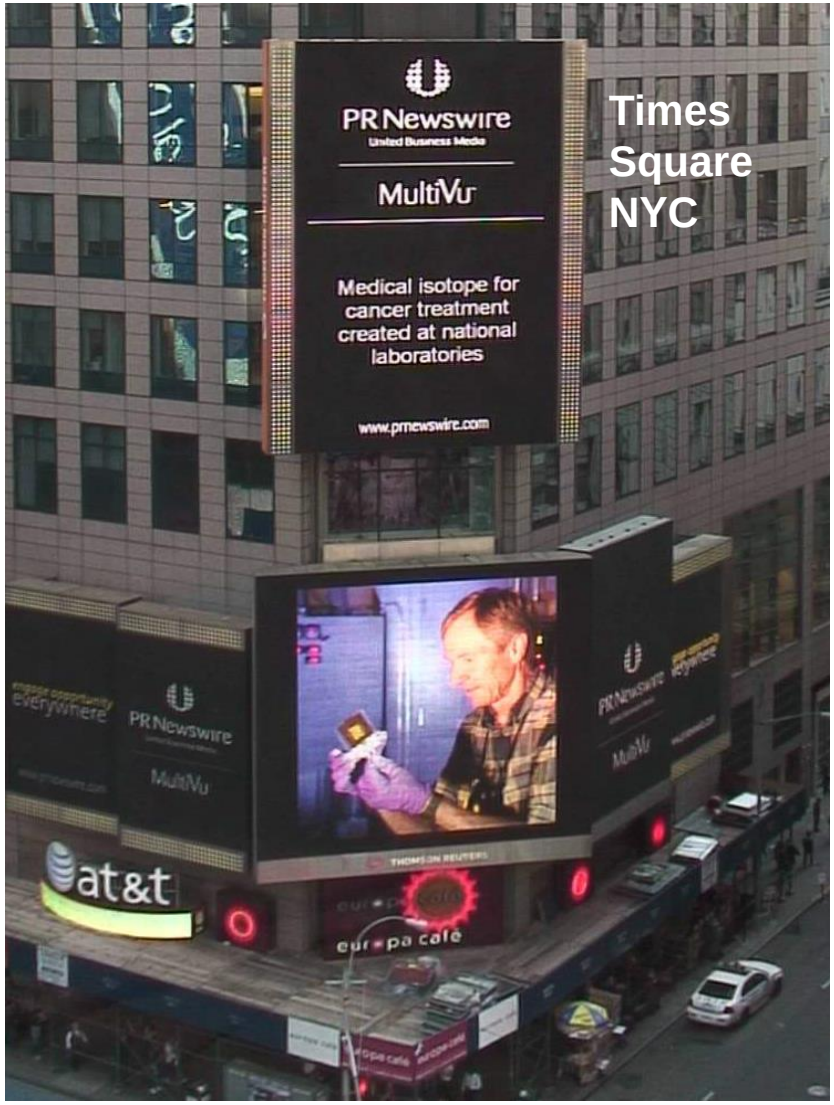
More than 470 shipments in FY2013

Isotopes and Radioisotopes in Short Supply Provided at Full Cost Recovery

Some key isotopes and radioisotopes and the companies that use them

Strontium-82, Rubidium-82	Imaging / Diagnostic cardiology
Germanium-68, Gallium-68	Calibration / PET scan imaging
Californium-252	Oil and gas exploration and manufacturingcontrols
Selenium-75	Radiography / Quality control
Actinium-225, Yttrium-90, Rhenium 188	Cancer / Infectious disease treatment
Nickel-63	Explosives detection at airports
Gadolinium-160, Neodymium-160	Tracers and contrast agents for biological agents
Iron-57, Barium-135	Standard sources for mass spectroscopy
Sulfur-34	Environmental monitoring
Rubidium-87	Atomic frequency / GPS applications
Lithium-6, Helium-3	Detection of Special Nuclear Materials
Samarium-154	Solar energy /transportation applications

From Discovery to Deployment: R&D Creates New Production Method for Actinium-225



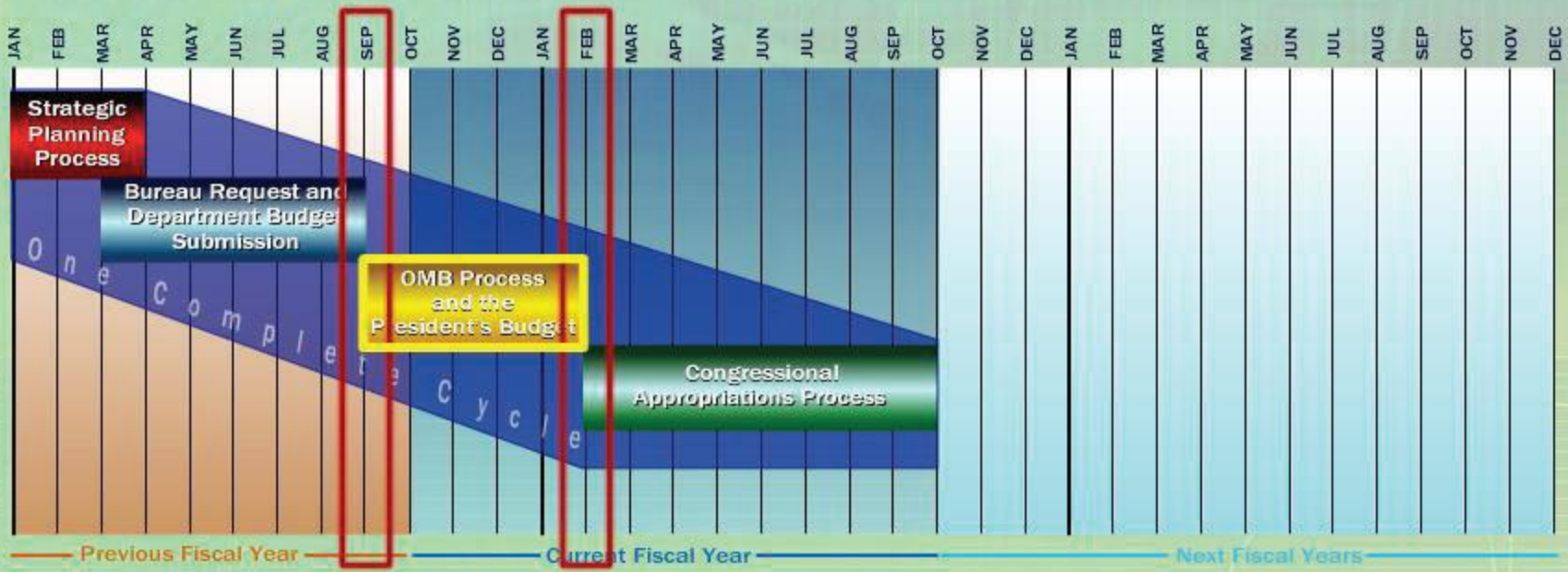
- A new isotope project at LANL shows promise for rapidly producing major quantities of a new cancer-treatment agent, actinium 225.
- Using proton beams, LANL and BNL could match current annual worldwide production of the isotope in just a few days.
- A collaboration among LANL, BNL, and ORNL is developing a plan for full-scale production and stable supply of Ac-225.
- Ac-225 emits alpha radiation. Alpha particles are energetic enough to destroy cancer cells but are unlikely to move beyond a tightly controlled target region and destroy healthy cells. Alpha particles are stopped in their tracks by a layer of skin—or even an inch or two of air.

Office of Science FY 2014 Budget Request to Congress

	FY 2012		FY 2013		FY 2014		
	Enacted Approp.	Current Approp.	Annualized CR[1/]	Estimated CR with Sequester	President's Request	FY14 vs. FY12 Enacted	
Science							
Advanced Scientific Computing	440,868	428,304	443,566		465,593	+24,725	+5.6%
Basic Energy Sciences	1,688,093	1,644,767	1,698,424		1,862,411	+174,318	+10.3%
Biological and Environmental Research	609,557	592,433	613,287		625,347	+15,790	+2.6%
Fusion Energy Sciences	400,996	392,957	403,450		458,324	+57,328	+14.3%
High Energy Physics	790,860	770,533	795,701		776,521	-14,339	-1.8%
Nuclear Physics	547,387	534,642	550,737	519,904	569,938	+22,551	+4.1%
Workforce Development for Teachers and Students	18,500	18,500	18,613		16,500	-2,000	-10.8%
Science Laboratory Infrastructure	111,800	111,800	112,485		97,818	-13,982	-12.5%
Safeguards and Security	80,573	80,573	81,066		87,000	+6,427	+8.0%
Program Direction	185,000	185,000	186,132		193,300	+8,300	+4.5%
SBIR/STTR (SC)	—	114,125	—		—	—	—
Subtotal Science	**4,873,634**	**4,873,634**	**4,903,461**		**5,152,752**	**+279,118**	**+5.7%**
SBIR/STTR (DOE)	—	61,346	—		—	—	—
Total Science Appropriation	**4,873,634**	**4,934,980**	**4,903,461**		**5,152,752**	**+279,118**	**+5.7%**

[1/] Annualized CR per FY 2014 President's Budget (= FY 2012 + 0.612%)

THE OMB BUDGET REVIEW PROCESS



The President has to transmit his budget to the Congress in early February

THE CONGRESSIONAL APPROPRIATIONS PROCES

PAUSE PLAY PREV NEXT click next to contin

Start of the fiscal year

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV

Strategic Planning Process

Bureau Request and Department Budget Submission

OMB Process and the President's Budget

Congressional Appropriations Process

Strategic Planning Process

Bureau Request and Department Budget Submission

OMB Process and the President's Budget

Congressional Appropriations Process

Strategic Planning Process

Bureau Request and Department Budget Submission

One Complete Cycle

Previous Fiscal Year — Current Fiscal Year — Next Fiscal Years

My History

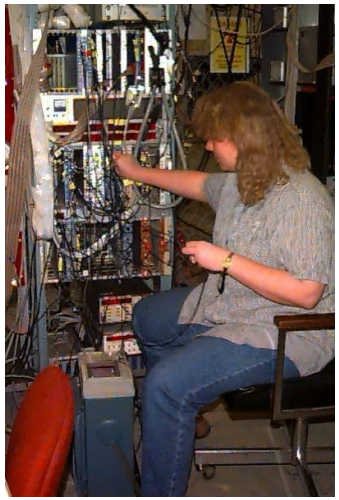
Small college – chemistry

Ph.D. large school – Nuclear science
(heavy ion physics)

Postdoc – Los Alamos National Lab

Staff Member – Los Alamos National Lab
Brookhaven National Lab
CERN (Switzerland)

Year 2000 - DOE



A Day in the Life Of….

- Senior Executive Service
- I supervise a Division of program managers, support staff and budget analysts
- I mentor detailees (temporary staff), students, other DOE staff
- Strategic direction and planning
- Budget formulation and execution
- Facility operations and performance, upgrades – reviews with peer panels
- Build big and small pieces of instrumentation; help project teams; reviews; monitor project performance
- International working groups on specific DOE interests – SC User Facility Working Group
- Interact and collaborate with international funding agencies
- Chair or participate in White House working groups
- Respond to Congressional inquiries
- Testify to Congress
- Never a dull moment
- Learn, learn, learn

A little bit about me…

Family is very important to me

Conclusions

- As a scientist, important to be knowledgeable of what directs the national program to understand where the opportunities lie

- As a scientists, important to play a role in the strategic development of your scientific program.
  - You have a voice! You have a vote!
  - Community strategic meetings often held through professional societies.

- As a scientists, important to support your national program
  - Public Outreach
  - Writing letters of support
  - Congressional visits

- As a female scientist, important to know that there is nothing holding you back – Go for it! It is possible to have it all!

- jehanne.gillo@science.doe.gov